then it follows apparently from this agreement, when account is taken of (2), that the plastic deformation of Pb at helium temperatures is determined by the electronic drag of the dislocations and corresponds to those dislocation-motion models in which $V \sim (1/B_e)$, where B_e is the electronic voscisity (e.g., the viscous model).

The fact that the values of $2\Delta(0)/kT_c$ that ensure agreement of (3) with the temperature dependence of $\Gamma(t_{SN})$ do not differ, within the limits of the experimental error, from the values of $2\Delta(0)/kT_c$ measured by the known methods (see, e.g., [5]), may possibly indicate that the energy gap in Pb does not change noticeably in the elastic fields of the moving dislocations.

B_S/B_N is described by the function (3) if the electron viscosity B_N in the N state is independent of the temperature, as in [1], and if the electric pairs are not destroyed during the motion of the dislocations (i.e., the dislocation velocities are not very large, see [6]). Thus, it can apparently be concluded that B_N of the employed Pb samples does not depend on the temperature, and that the motion of the dislocations in plastic deformation of Pb does not cause destruction of the electron pairs.

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PROBABILITY OF RESONANT 23.8-keV γ RADIATION FROM Sn^{119} AND ANHARMONICITY OF ATOMIC VIBRATIONS IN FERROELECTRICS OF THE PEROVSKITE TYPE

M.V. Plotnikova, K.P. Mitrofanov, and Yu.N. Venevtsev
Nuclear Physics Institute of the Moscow State University
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Precision NGR measurements were made on the impurity Sn^{119} nuclei in the ferroelectrics $BaTiO_3$ and $PbTiO_3$ and in the antiferroelectric $PbZrO_3$. The character of the temperature dependence of the Mossbauer-effect probability has made it possible to conclude that low-temperature anharmonicity is present in the lattice vibrations of $BaTiO_3$ and $PbTiO_3$ in the entire temperature range of existence of these crystals.

One of the central problems of ferroelectricity is the development of a quantum-mechanical theory that takes anharmonic effects into account. There are no experimental data, however, on the character of the anharmonicity in ferroelectrics. NGR is capable of yielding valuable and in a number of cases unique information on this subject. Knowledge of the absolute value of the

Mossbauer-effect probability f and of its temperature dependence makes it possible to estimate the degree of the anharmonicity of the atomic oscillations and to determine the values of certain dynamic parameters of the crystal [1, 2].

Experimental studies of NGR in ferroelectrics have yielded information on the behavior of the relative value of f and of other Mossbauer parameters in a relatively narrow temperature region near the phase transitions. A number of such experiments have revealed anomalous changes in the γ spectra near the Curie points T_c (e.g., [3]). Other investigations did not disclose such effects ([4, 5] among them).

We present here, for the first time, the temperature dependences of the absolute value of f(T) and the dependence of the isomeric chemical shift $\delta(T)$ for the impurity atoms Sn^{119} in the ferroelectrics $BaTiO_3$ and $PbTiO_3$ and in the antiferroelectric $PbZrO_3$. The investigations were made in the temperature range from 77 to 1000°K. The results have made it possible to observe low-temperature anharmonicity of the tin-ion vibrations in $BaTiO_3$ and $PbTiO_3$. We estimate the dimensions of the central flat part of the potential well for the tin ions in the cubic phase of these ferroelectrics.

The use of a resonant counter [6, 7] to measure the emission spectra of the samples has increased the ratio of the useful signal to the background by up to 6 times and has ensured high measurement accuracy. The error was 2% for the absolute value of f and ±0.003 mm/sec for δ. The measurements near the phase transitions were made with particular care and were repeated many times, with good reproducibility of the results.

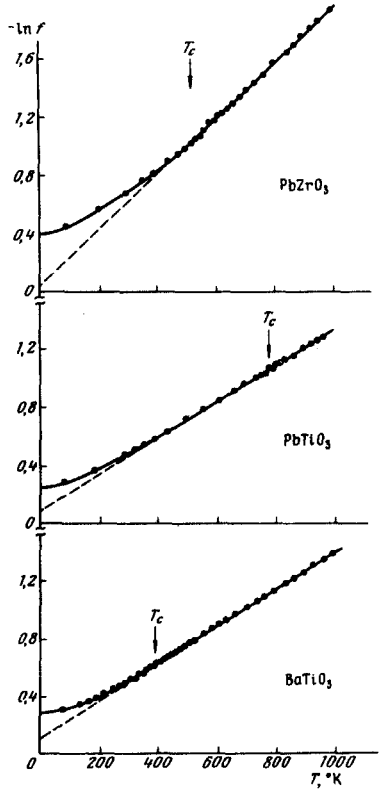

Fig. 1. f(T) plots for Sn^{119} in the lattices of $BaTiO_3$, $PbTiO_3$, and $PbZrO_3$.

The investigated $PbTiO_3$, $BaTiO_3$ and $PbZrO_3$ polycrystals, to which 1 at.% radioactive Sn^{119} was added, were prepared by the standard ceramic technology. It is known that the Sn^{4+} in these substances, with the perovskite structure ABO_3, occupy sites of the ions B at centers of oxygen octahedra. The distinctive dielectric properties and the Curie points of these compounds are little altered by low tin concentrations.

The Mossbauer spectra of all the samples consisted of a single line, weakly broadened to different degrees, and shifted relative to the $BaSnO_3$ line. The widths and shapes of the spectra did not change when the temperature changed.

The f(T) and $\delta(T)$ plots shown in Figs. 1 and 2 are smooth and have no anomalous jumps in the entire investigated temperature range. Above 300 - 500°K, the plot of f(T) becomes a straight line and reaches its classical limit. On the whole, f(T) for $BaTiO_3$ and $PbTiO_3$ are close to the theoretical curves calculated with the Einstein model, but raised somewhat in the vertical direction. This form of f(T) is typical of an atom whose vibrations reveal the so-called low-temperature anharmonicity [2]. The low-temperature anharmonicity takes place in the entire temperature region of crystal existence, and is connected with the special shape of the potential well, in which the walls are steeper and the bottom seemingly

flatter than for the harmonic potential. In real cases, the relief of the central part of the well is quite complicated, but the bottom is assumed to be flat for simplicity. From the intercept of the extrapolated linear section of f(T) with the ordinate axis it is possible to estimate approximately the radius R of the flat part of the bottom of the potential [2]. The results of such estimates are listed in the table, which gives also the squared amplitudes $\langle x^2 \rangle_0$ of the zero-point oscillations of the Sn^{119} ions, obtained by extrapolating f(T) to 0°K, and the Debye temperatures Θ_D calculated from the slopes of the high-temperature sections of f(T).

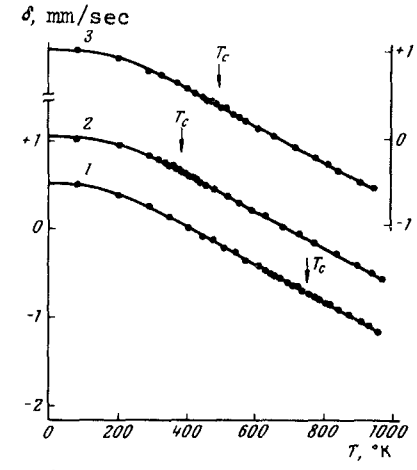

Fig. 2. Curves 1, 2, 3 - plots of δ(T) for Sn^{119} in lattices of $PbTiO_3$, $BaTiO_3$, and $PbZrO_3$ (the right-hand scale pertains to curve 3).

An appreciable anharmonic distortion has been obtained for the Sn ion in $BaTiO_3$ and $PbTiO_3$, where the displacements of the Ti ions relative to the oxygen octahedra in the ferroelectric phase are large. Practically no low-temperature anharmonicity was noted in the case of $PbZrO_3$, where the displacements of the Zr ions are small below T_c.

Similar measurements of the absolute value of f(T) in the compounds $BaSnO_3$ and $CaSnO_3$ have shown absence of low-temperature anharmonicity. These results give grounds for assuming that the low-temperature anharmonicity in the vibrations of the Sn impurity atom is connected with the special dielectric properties of $BaTiO_3$ and $PbTiO_3$ and characterizes the vibrations of the B-sublattice ions in these ferroelectrics. The fundamental fact is that the low-temperature anharmonicity in these ferroelectrics exist both in the ferroelectric phase and in the entire paraelectric region.

Sample	Θ_2, °K	R, Å	$\langle x^2 \rangle_0$, Å^2
	368 ± 2	0,024	0.19×10^{-2}
	371 ± 2	0.017	0.15×10^{-2}
	305 ±2	0,065	0.28×10^{-2}

It is also important to note that the smoothness of δ(T) indicates the absence, accurate to 0.1%, of jumplike changes of the ionicity of the B-O bond in the phase transitions in all the investigated systems.

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